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Microalgae: An alternative natural source of bioavailable omega-3 DHA for promotion of mental health in East Africa

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ABSTRACT

Mental health illness associated with poor nutrition is a serious public concern worldwide. The most at risk individuals are children and adolescents in the developing world. Deficiencies in omega-3 DHA fatty acids have long been recognized as a major contributing factor for mental health illnesses. Provision of products rich in omega-3 DHA could address this problem. But most commonly used products do not have preformed omega-3 DHA, making them less suitable for prevention of mental illnesses in resource-poor countries. The objective of this study was to provide a narration of the best alternative source of bioavailable omega-3 DHA for promotion of mental health in developing countries. This study identified microalgae as the best natural source of preformed omega-3 DHA over fish oil which has been reported to contain heavy metals, antibiotics and other contaminants that may pose a serious safety concerns to consumers. The study has further narrated future opportunities around microalgae in East Africa. One of the opportunities is development of a business model that could accelerate sustainable production and utilization of microalgae for improved nutrition and health in Eastern Africa.

Introduction

General state of mental health disorders

Poor mental health remains a public concern worldwide. The global burden of mental health problems is high, and is predicted to rise in the near future. The most at risk individuals are children, adolescents and women of reproductive age in developing countries. The 2016 World Bank Group and World Health Organization estimates [1] indicate that more than 10% of the global population is affected by mental disorders, of which 20% are children and adolescents. In actual fact, mental disorders account for 30% of non-fatal disease burden globally and 10% of overall disease burden, including death and disability in the world. Low- and middle income countries contribute about 80% of individuals who are likely to suffer

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from a form of mental disorder in their lifetime. The devastating situation of mental health problem in developing countries underscores the need for setting a sustainable approach to address the issue. If the problem is left unattended, it may lead to adverse socio-economic consequences at both individual and community levels.

Socio-economic consequences of mental health disorders

Mental disorder accounts for almost one in three years lived with disability people worldwide [1]. It imposes enormous economic burden arising from the lost economic output linked between mental disorders and costly, potentially fatal conditions such as cancer, cardiovascular disease, diabetes, and obesity [2]. The recent World Bank estimates show that "the lost economic output caused by untreated mental disorders as a result of diminished productivity at work, reduced rates of labor participation, foregone tax receipts, and increased welfare payments amounts to about US$1 trillion per year" [1]. And more than 54% of the estimated global cost of mental disorders was borne by developing countries and by 2030 that cost is projected to reach 58%. Thus, these socio-economic impacts of mental health disorders underscore the need for reducing the prevailing burden of mental health disorders at the household level and national level. And the only sustainable method for reducing the burden caused by mental health disorders is prevention [3].

Poor nutrition as a major cause of mental health disorders

Poor nutrition has long been recognized as one the contributing factors of mental illnesses among individuals in developing countries [4]. Omega-3 fatty acids, B vitamins, minerals, and amino acids which are precursors to neurotransmitters are the most common nutrient deficiencies seen in patients with mental illnesses [5]. This implies that provision of products that are rich in omega-3 fatty acids, particularly the one with high biological value could address the problem of mental disorders in the affected population. Evidence from previous studies show that nutrient-based supplements have a potential to provide various neurochemical modulatory activities that are beneficial in the prevention of mental health disorders [6]. However, the most commonly used omega-3 products, especially in developing countries do not contain bioavailable omega-3 DHA. This underscore the need for looking a safe source of bioavailable omega-3 DHA and other essential nutrients that are direct linked to prevention of mental health illnesses.

Omega-3 based interventions for addressing mental health disorders

The field of nutrition has recently received attention as a sustainable solution for the prevailing mental disorders in both low and high income countries [7,8]. The assertion is based on clinical trials which have shown that nutrient-based supplements provide various neurochemical modulatory activities that are essential for preventing mental health disorders [6]. Success stories of clinical trials have prompted scientists to develop a number of nutrient-based interventions to promote mental health in the world [9]. Supplementation of omega-3 fatty acids, particularly, docosahexaenoic acid (DHA) is an example of available nutrient-based interventions which have shown promising results in improving mental health. A number of studies have demonstrated usefulness of omega-3 DHA in preventing and or treating mental health disorders [10,11]. Some of the reported mental disorders which have been treated using omega-3 DHA include bipolar depression, major depressive disorder, post-traumatic stress disorder and psychosis.

A mechanism on which omega-3 DHA provides neurochemical modulation activities have been described elsewhere [11]. Briefly, the mechanism includes; "modulation of neurotransmitter re-uptake,degradation, synthesis, and receptor binding; anti-inflammatory and antiapoptotic effects; and the enhancement of cell membrane fluidity and neurogenesis via upregulation of brain-derived neurotrophic factor (BDNF)" [11]. Some other nutrients that boost the activity of omega-3 DHA in the central nervous system include S-adenosyl methionine (SAMe), N-acetyl cysteine (NAC), zinc, B vitamins, folate, magnesium, vitamin C, and vitamin D [10,11]. This means that nutrient-based interventions that consider using sources or products that are rich in both the omega-3 DHA and its cofactors are likely to have a more significant impact on mental health improvement.

Prevailing sources of omega-3 DHA and their drawbacks

The omega-3 DHA cannot be produced *de novo* in human body, instead, it can be obtained directly from the diet or synthesized from a precursor known as alpha-linolenic acid (ALA) [11]. Currently, fish oil is the major source of omega-3 DHA. However, several drawbacks related to the use of fish oil as the source of omega-3 have been reported in the literature [12]. Fish oil possesses undesirable odors, flavors, and tastes which discourage consumers from consuming it in its pure form. Furthermore, it has been reported that fish oils contain high levels of methyl-mercury, heavy metals and antibiotics, creating a risk of poisoning the consumers. Also, environmental contaminants such as dichlorodiphenyltrichloroethane (DDT), dioxins and polychlorinated biphenyls have been found in fish oil, all these discourage the use of fish oil [12]. Fish oil is also very expensive, thus, may not be afforded by majority of individuals in developing countries. In addition, the production of fish oil has reached the optimal threshold and is declining throughout the world. In this view, there is a need to look for sustainable and safe sources of omega-3 DHA.

Dietary ALA could be the alternative source of omega-3 DHA [13]. This is because our body can turn dietary ALA into omega-3 DHA, and that the ALA-rich foods are almost found everywhere on this earth. Some of foods that are rich in ALA include walnuts, soybeans, flaxseeds, chia seeds, canola, and many other nuts and seeds. Beans, legumes, and wheat germ are also high in omega-3 ALA [14]. Several foods and food products that are rich in ALA are available on the global market and are being advertised as food for brain development and cognitive function in all age groups. People believe that since our bodies can make DHA out of ALA, eating more omega-3 ALA foods would help them get enough DHA. Unfortunately, the body is not very good at turning omega-3 ALA into omega-3 DHA [12]. Reasons to such inefficiency in ALA conversion are not clearly stated. However, some evidence show that poor levels of cofactors such as zinc, magnesium, vitamin C, proteins, and B vitamins and too much omega 6 in the body slowdown the rate of synthesizing DHA from ALA in the body [15].

Although adequate levels of cofactors and the optimal ratio of omega-3 to omega-6 increase the synthesis of DHA from ALA, the output of this metabolic activity may not confer physiological benefits in the brain [16]. Thus, individuals who solely depend on ALA-rich foods for their DHA are likely to be deficient in this important polyunsaturated fatty acid. The deficiency in DHA is very common among the individuals in developing countries, probably because they rely only on ALA-foods for their DHA. Evidence from the recent global estimates of dietary DHA shows that "the vast majority of young children in developing countries fall well short of the recommended intake (100 mg/day) of DHA omega-3 fatty acid [17]. This highlights the need for setting a robust strategy to improve the DHA status in resource-poor communities.

Microalgae as the best alternative source of bioavailable omega-3 DHA

The inability of ALA metabolism to confer the physiological need of DHA in human brain has prompted the need for alternative sources of bioavailable omega-3 DHA. Consumption of natural ingredients or diets rich in preformed DHA offers a promising approach of conferring the physiological need of DHA in the body. This is particularly important especially during fetal and neonatal development, the period when demands for DHA in the central nervous system cannot readily be met by ALA alone [11]. The primary source of food for wild fish could be the appropriate and sustainable source of dietary preformed DHA. This is because; even fish themselves cannot synthesize DHA *de novo* in their body [18]. They obtain their DHA from the foods they eat, normally phytoplankton (microalgae).

Microalgae is the best alternative natural source of bioavailable omega-3 DHA and other essential nutrients such as iron, zinc, vitamin B3, vitamin B6, vitamin C, vitamin E and magnesium, some of which are cofactors for the synthesis of DHA from ALA in the body. Because of this, microalgae was recently pointed out by 130 national academies of science and medicine as one of the innovative foods that can bring co-benefits to human health and climate in the near future. Increased consumption of microalgae will replace meat consumption in some regions and hence reduce emission of greenhouse gases that emanates from the meat. So, microalgae have multiple benefits such as promotion of nutrition and health, generation of income to smallholder farmers, and mitigation of climate change in developing regions like East Africa.

Future research opportunities around microalgae in East Africa

A number of microalgae species have been identified across the globe. The typical largest homes of microalgae are Japan, the Philippines, China, and South Korea, followed by Vietnam, Chile, and Eastern Africa (Tanzania in particular) [19]. Unlike other countries, Eastern Africa has not yet fully exploited the potential of microalgae to improve nutrition and health in the region. So far, there is no scientific information regarding the nutritional and phytochemical profiles of microalgae found in the region. This limits practitioners from incorporating microalgae in nutrient-based interventions for improving status of omega-3 DHA among the individuals in the region. This stresses the need to identify microalgae species in the region and establish their scientific evidence in improving nutrition and health. This scientific information will help nutritionists and other health practitioners develop formulations or products rich in preformed omega-3 DHA for prevention of mental health disorders in the region.

A proper business model that can link microalgae smallholder farmers and processors is also needed in the region. This model is very important as it will accelerate optimal utilization of microalgae in the region. Optimization techniques like linear programming (LP) [20] can be deployed to ensure keen execution of the model along the microalgae chain. Linear programming (LP) "is a mathematical tool which allows generation of optimal solutions that satisfy prescribed constraints at once" [20]. The tool can be used to optimize production conditions for microalgae. It can also be used by microalgae processors to formulate products that are rich in preformed omega-3 DHA and other essential nutrients [21]. This tool can also be used to inform regulatory authorities to design appropriate policies and dietary guidelines for omega-3 DHA that are currently missing in East Africa.

Declaration of Competing Interest

Authors have no conflict of interest to declare.

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References

[1] World Bank Group/WHO. Out of the shadows: making mental health a global development priority. 2016.
[2] D. Vigo, G. Thornicroft, R. Atun, Estimating the true global burden of mental illness, Lancet Psychiatry 3 (2) (2016) 171–178.
[3] WHO, in: Mental Health Atlas, WHO, 2014, p. 72.
[4] L. Korn, Nutrition Essentials for Mental Health: A complete Guide to the Food-Mood Connection, WW Norton & Company, 2016.
[5] T.S.S. Rao, M.R. Asha, B.N. Ramesh, K.S.J. Rao, Understanding nutrition, depression and mental illnesses, Indian J. Psychiatry 50 (2) (2008) 77.
[6] S. Forsyth, S. Gautier, N. Salem Jr., Dietary intakes of arachidonic acid and docosahexaenoic acid in early life – with a special focus on complementary feeding in developing countries, Ann. Nutr. Metab. 70 (3) (2017) 217–227.
[7] W. Marx, G. Moseley, M. Berk, F. Jacka, A. Health, Nutritional psychiatry: the present state of the evidence, in: Proceedings of the Nutrition Society, 2017, pp. 1–10.
[8] U. Ramakrishnan, B. Imhoff-Kunsch, A.M. Digirolamo, Role of docosahexaenoic acid in maternal and child mental health, Prostaglandins Leukot. Essent. Fatty Acids 89 (3) (2009) 958–962.
[9] M.L. Panse, S.D. Phalke, World market of omega-3 fatty acids, in: M.V. Hegde, A.A. Zanwar, S.P. Adekar (Eds.), Omega-3 Fatty Acids: Keys to Nutritional Health, Springer International Publishing, Cham, 2016, pp. 79–88.
[10] Thome Research Inc, Docosahexaenoic acid (DHA), Altern. Med. Rev. 14 (4) (2009) 391–399.
[11] G.Y. Sun, A. Simonyi, K.L. Fritsche, D.Y. Chuang, M. Hannink, Z. Gu, et al., Docosahexaenoic acid (DHA): an essential nutrient and a nutraceutical for brain health and diseases, Prostaglandins Leukot. Essent. Fat Acids 136 (2018) 3–13.
[12] K. Lane, E. Derbyshire, W. Li, C. Brennan, Bioavailability and potential uses of vegetarian sources of omega-3 fatty acids: a review of the literature, Crit. Rev. Food Sci. Nutr. 54 (5) (2014) 572–579.
[13] A.F. Domenichiello, A.P. Kitson, R.P. Bazinet, Is docosahexaenoic acid synthesis from alpha-linolenic acid sufficient to supply the adult brain? Prog. Lipid Res. 59 (2015) 54–66.
[14] G. Lenihan-Geels, K.S. Bishop, L.R. Ferguson, Alternative sources of omega-3 fats: can we find a sustainable substitute for fish? Nutrients 5 (4) (2013) 1301–1315.
[15] A.V. Saunders, B.C. Davis, M.L. Garg, Omega-3 polyunsaturated fatty acids and vegetarian diets, Med. J. Aust. 1 (2) (2012) 22–26.
[16] Gillingham B.L. The metabolic fate of alpha linolenic acid (ALA). IHP Mag. 2013; (November/December):72–9.
[17] S. Forsyth, S. Gautier, N. Salem Jr., Global estimates of dietary intake of docosahexaenoic acid and arachidonic acid in developing and developed countries, Ann. Nutr. Metab. 68 (4) (2016) 258–267.
[18] P.M. Dewick, Medicinal Natural Products: A Biosynthetic Approach, 3rd ed., John Wiley & Sons, Ltd, 2009.
[19] G. Rajauria, L. Cornish, F. Ometto, F.E. Msuya, R. Villa, in: Identification and Selection of Algae For food, feed, and Fuel applications. Seaweed Sustainability, Elsevier Inc., 2015, pp. 315–346.
[20] F. Dibari, E.H.I. Diop, S. Collins, A. Seal, Low-cost, ready-to-use therapeutic foods can be designed using locally available commodities with the aid of linear programming, J. Nutr. 142 (5) (2012) 955–961.
[21] F. Cahyaningrum, I. Permadhi, M.R. Ansari, E. Prafiantini, P.H. Rachman, R. Agustina, Dietary optimisation with omega-3 and omega-6 fatty acids for 12-23-month-old overweight and obese children in urban Jakarta, Asia Pac. J. Clin. Nutr. 25 (November 2017) (2016) S62–S74.